A Computational Approach to the Study of Diabetes Mellitus

SHORT SYNOPSIS

Submitted in partial fulfillment of the requirement of the degree of

DOCTOR OF PHILOSOPHY

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I hereby declare that the short synopsis entitled "A Computational Approach to the Study of Diabetes Mellitus" is an original piece of work done by research scholar Deepti under the supervision of Dr.Ruchi Gupta and co-supervision of Dr. Deepak Kumar for the degree of Doctor of Philosophy in the Department of Sciences (Mathematics) under the School of Sciences of Manav Rachna University, Faridabad during the academic year 2025-26.

Further, it is certified that the short synopsis is within the plagiarism limit, and a copy of the same is attached as per the University norms.

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ABSTRACT

The main purpose of biomathematics is to develop mathematical models of biological processes with the help of variety of applied mathematical tools and analytics. Diabetes is metabolic disease occurs in person having high blood glucose level. There are many hormones in body which controls the blood glucose level. Through this work, we can understand how each hormone affects the blood glucose level in our body. This model also helps in understand differential equation for change in concentration of glucose, insulin in which various factors like physical exercise and carbohydrates affects glucose concentration. In this, effect of different food consumption which increase and decreases the glucose level also analysed.Routh Hurwitz and Sylvester criteria is being for analyzing the stability.MATLAB is used for drawing graphs. The outcome of these mathematical model will be helping in prevent the early mortality and control diabetes. Through population model it can be understand that how many people will be suffering from this disease so that early preventive measure like proper medication and facilities can be planned. This study will be helping in prevent and control the globally increasing diabetic population. An ordinary person can also understand this study and can move on daily physical exercises and healthy eating. Accordingly, there is a great deal of work to be done in this subject.

Keywords: Biomathematics, Mathematical Models, Diabetes, Differential Equations, MATLAB, Genetic algorithm.

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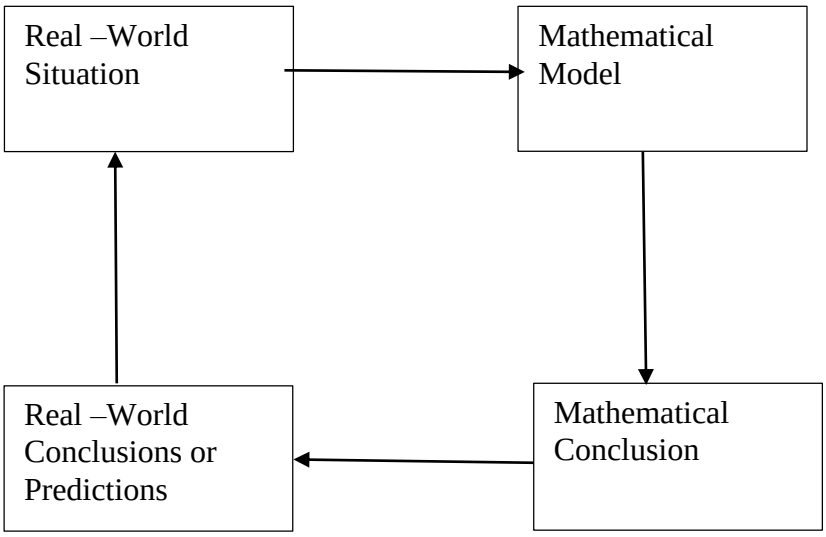
1. INTRODUCTION

A branch of science called biomathematics studies the various ways that mathematics is used in biology and medicine. Biology and Medicine are two subjects in which mathematicians can do research. Continuously using math to understand life science and medicine. A biological process is a complex process. We can easily understand this through a mathematical model.

To create a mathematical model, we have to follow the steps given below.

• Find the problem that needs research.
• Identify the key factors that will be needed for research.
• Represent those factors and their interactions mathematically.
• Analyze the mathematical relationships.
• Describe the mathematical findings in terms of the actual occurrence.
• Evaluate the results' applicability to the actual scenario.
• If necessary, reexamine the initial model's structure and factors that were taken into consideration.



When glucose level is increases in our body it creates a diabetes, also called hyperglycemia. This is a long lasting disease. Insulin is the hormone which control the glucose level in human body.

When insulin does not function properly then diabetes issues starts in our body. Main symptoms of diabetes are feeling very thirsty, frequent urination, feeling very tired and blurry vision.

There are three types of diabetes: Type 1 diabetes, type 2 diabetes and gestational diabetes

In type 1 diabetes the body does not make insulin. When in absence of insulin the blood glucose level in our body will not be control. Consequently, type 1 diabetes will occur. It was once referred to as "juvenile diabetes" or "Insulin-Dependent Diabetes Mellitus (IDDM)".This mostly happens in youngsters and kids. But this type 1 diabetes is not so common as like type 2 diabetes.

Type 2 diabetes is most common type of diabetes in which body does not create required insulin. This is also called insulin resistance. Obesity is the main reason of this disease.

Gestational diabetes happens in pregnancy. Usually, this occurs around 24^{th} week of pregnancy and this type of diabetes does not have any symptoms. It is recommended to get diabetes test in between 24^{th} to 28^{th} week of pregnancy .This is similar to type 2 diabetes. In this case, after delivery, baby is also having chances of diabetes.

2. LITERATURE REVIEW

Sari et al. (2023) have formulated a model to analyze blood sugar levels for diabetic patients using a bi-response truncated spline non-parametric regression model. There were two response variables in this model – postprandial and fasting blood sugar levels. Simultaneously, triglyceride and cholesterol levels were used as predictors in this model. In this study, for parameter estimation-weighted least squares (WLS) and to find the ideal number of spline knots - Generalized Cross-Validation (GCV) was used. The best model used three knot points, with a GCV of 8.573 and a high R^2 of 99.625% - demonstrates model fit. This study shows that frequent complex health and non-linear relationship data can be understood through non-parametric approaches.

To investigate the impact of scarce hospital resources on the development of diabetes in Kenya, Andima et al. (2022) created a mathematical model. In this model population was divided into four groups: hospitalized people, diabetes patients, susceptible people and people with problems. This study shows that if there is change in lifestyle, there can be an increase in susceptible people, while there could be a decrease in diabetic cases. On the other hand, an increase in health care facilities puts less stress on the existing healthcare system, while increase in hospitalisation admission rate put more stress.

Koideere et al. (2020) has created a compartmental model in which six compartments genetic healthy people, genetic and behavioural pre-diabetic groups, and diabetes patients with no difficulties and those with manageable or severe complications. In this study Pontryagin's Maximum principal is used mainly as an optimal control. Iterative method is used to solve optimality of the system. This research shows that for controlling diabetes, behavioural care is also important apart from clinically health care.

As per a Study by Khurana et al. (2019), medical plants can help in managing type 1 diabetic mellitus (T1DM), supporting earlier research showing that the natural compounds in these plants have healing effects. Studies have shown that bitter melon (Momordica charantia) and fenugreek (Trigonella foenum-graecum) can help lower blood sugar, making them useful in managing diabetes. Similarly, natural herbs like turmeric and aloe vera also give an indication to drop the

fasting blood sugar levels, so they are helpful in managing diabetes. In docking experiments, it is evident that Indian medical herbs like taraxerol and obtusifoliol also have substantial binding affinities which can be used in the treatment of type 1 diabetes. This shows that traditional herbal remedies in combination with computer modelling present a path to improve diabetic treatment plans.

To enhance diabetes mellitus diagnosis, Tyagi et al. (2024) investigated the potential use of genetic algorithms (GA). In this study, through the differential equations, the glucose-insulin system was modelled. In this study, GA as an optimization tool in MATLAB was used to analyse the normal, prediabetic and diabetic patients. With the help of GA's evolutionary computing methodology, researchers were able to showcase results using a fitness plot and find the best diagnostic patterns. Findings of this study, GA successfully increases diagnosis accuracy by managing the intricacy of biological data. This study has concluded that heuristic approaches like GA helps tackle the growing incidence of diabetes, especially in countries like India, where metropolitan and standard of living upgradation choices are accelerating the diabetic cases. In addition to this, it is evident that eventually biomathematics and evolutionary computing will have to be integrated. This study also shows that in the future combination of biomathematics and evolutionary computing will be helpful to improve diabetic research and care.

By Kumar, D. (2019) introduce a model to investigate gestational diabetes mellitus (GDM), which is a type of diabetes which occurs during pregnancy and can be dangerous for both mother and unborn child. Placental volume, beta-cell mass, insulin levels, glucose concentration and HbA1c are the important factors included in this model. In this study, using differential equations, it is demonstrated how these variables affect the regulation of glucose during pregnancy. For analysing the stability of the system, the Routh-Hurwitz criterion was used, while MATLAB simulation contributed visual insights. As per the results, changes in these parameters will have a drastic impact on glucose levels, accordingly, providing insight into the course of GDM. In this study, it is highlighted how this type of modelling helps in ascertaining preventive actions and improving gestational diabetes care techniques.

In this study, Gupta, R., & Kumar, D. (2017) has demonstrated that patient who take alcohol and having type 2 diabetes are more prone to coronary heart disease (CHD) and hypertension. If they avoid alcohol the risk of coronary heart disease (CHD) and hypertension is less. In this study with the help of differential equation, it shows that how life style decision can make diabetic more worst with coronary heart disease (CHD) and hypertension.

With the help of mathematical modelling Kumar et al. (2021) have presented a paper in which shows that a relationship between type 2 diabetes and cancer. In this model differential equations show how change in insulin, glucose and cancer cells with respect to time. In this study it has been found that patient with type 2 diabetes having more chancing of cancer comparatively patient with non-type 2 diabetes.

2. DESCRIPTION OF BROAD AREA/TOPIC

The main causes of diabetes are a mix of environmental and genetic factors. It is a metabolic condition characterized by unusually elevated blood sugar levels in the patient. The two primary types of diabetes are caused by either a decreased ability for the body to produce insulin (Type 1 diabetes) or a reduced ability for the body to respond to insulin (Type 2 diabetes).

Numerous natural phenomena are described by mathematics on a large scale. In the medical sciences, where it is nearly impossible to obtain data for many in vivo parameters, such as rate constants, mathematical modelling, in addition to stability analysis, allows for a qualitative description/understanding of systems in which one or more of the components are not sufficiently or accurately determined. This is partially the reason for this. Additionally, it can assist in estimating the factors that determine the expected dynamic behavior of a certain system.

Population models are crucial for diseases like diabetes. They tell us how many people are likely to develop diabetes in the future.This study will be highly beneficial in the field of medical sciences as it may assist reduce the rising number of people with diabetes. It is also presented in a way that the average person can easily grasp.

In order to decrease exposure to the established risk factors for diabetes and to enhance access to and caliber of care, coordinated action is required in the development of national and international policies.

A proper stochastic model is needed by the glucose regulating system to provide the treatment guide points for diabetics. It is possible to create optimality policies that determine factors like the amount of food consumed, the interval between meals, the amount of energy used for extra physical activity and physiological maintenance, etc. The model's sensitivity analysis is helpful in obtaining reliable indications of the diabetes mellitus regulating system.

4. OBJECTIVES OF THE STUDY /PROBLEM IDENTIFICATION

From a research perspective, biomathematics is quite interesting due to its applications in biology and medicine. Diabetes affects people of all ages and is not just a problem for those who are a certain age. Diabetes cannot be cured, but it can be managed with medication, hormone therapy, regular exercise, a balanced diet, and adherence to healthy lifestyle practices. The study's primary goal is to benefit society by reducing the difficulties associated with diabetes.

The following are the specific objectives:

1. **The primary objective of this study is to understand the factors influencing diabetes and the variations in diabetes outcomes and care for people.**

2. **To investigate the several parameters that are either directly or indirectly associated with diabetes mellitus and its consequences.**

3. **To examine all research that has been carried out before in the field of computational models for diabetes mellitus.**

4. **To develop an evolutionary algorithm for enhanced mathematical modelling of diabetes mellitus dynamics.**

5. METHODOLOGY TO BE ADOPTED

The steps to be taken when conducting research are as follows:

❖ Visit libraries and hospitals to gather data.

❖ Use mathematical approaches to execute a model utilizing the data acquired from these sources.
❖ Using computer programs such as Mathematical and MATLAB to solve differential equations and create graph.
❖ Application and development of a mathematical model with better starting points.
❖ Examining how enhanced analysis affects the model.
❖ Analyzing a few key diagnostic domains with model output.

Mathematical Technique

Basic Model: Glucose and Insulin Dynamics

1. **Variables:**
   G (t): Glucose concentration in the bloodstream at time t.
   I (t): Insulin concentration in the bloodstream at time t.

2. **Parameters:**
   a : Glucose production rate by the liver.
   b : Glucose utilization rate independent of insulin.
   c : Glucose utilization rate dependent on insulin sensitivity.
   d : Insulin secretion rate by pancreatic beta cells in response to glucose.
   e : Insulin clearance rate.

3. **Differential Equations:** The dynamics of glucose and insulin can be expressed as:

$$\frac{dG(t)}{dt} = a - bG(t) - cI(t)G(t)$$
$$\frac{dI(t)}{dt} = dG(t) - eI(t)$$

Explanation of the Model

Glucose Dynamics $\left(\frac{dG(t)}{dt}\right)$**:**

- a : Glucose enters the bloodstream due to liver production or food intake.

- $-bG(t)$: Glucose is removed independently of insulin (e.g., by basal metabolism).
- $-cI(t)G(t)$: Glucose is removed in an insulin-dependent manner, with higher insulin levels leading to increased glucose uptake by cells.

Insulin Dynamics $\left(\frac{dI(t)}{dt}\right)$**:**

- $dG(t)$: Insulin is secreted by the pancreas in response to blood glucose levels.
- $-eI(t)$: Insulin is cleared from the bloodstream.

Genetic Algorithm

John Holland dubbed the "father of genetic algorithms," created the genetic algorithm early in the1970s. The population models serve as the foundation for the evolutionary computer techniques [5]. The steps that make up GA's operations are as follows:

- Starting point: The algorithm starts when the first population (set of solutions) is created or selected at random.
- Selection: Find the best answers within a group.
- Fitness assessment: The fitness value of each solution is determined by how closely it resembles the ideal solution to the problem.
- Crossover: During this process, a mating pool serves as the site of the genetic information exchange among a set of solutions.
- Mutation: Finding the best answer, fresh children are produced from a single parent, and mutation is also taken into account.
- Elitism: Elitism is the preservation of a small number of excellent answers.

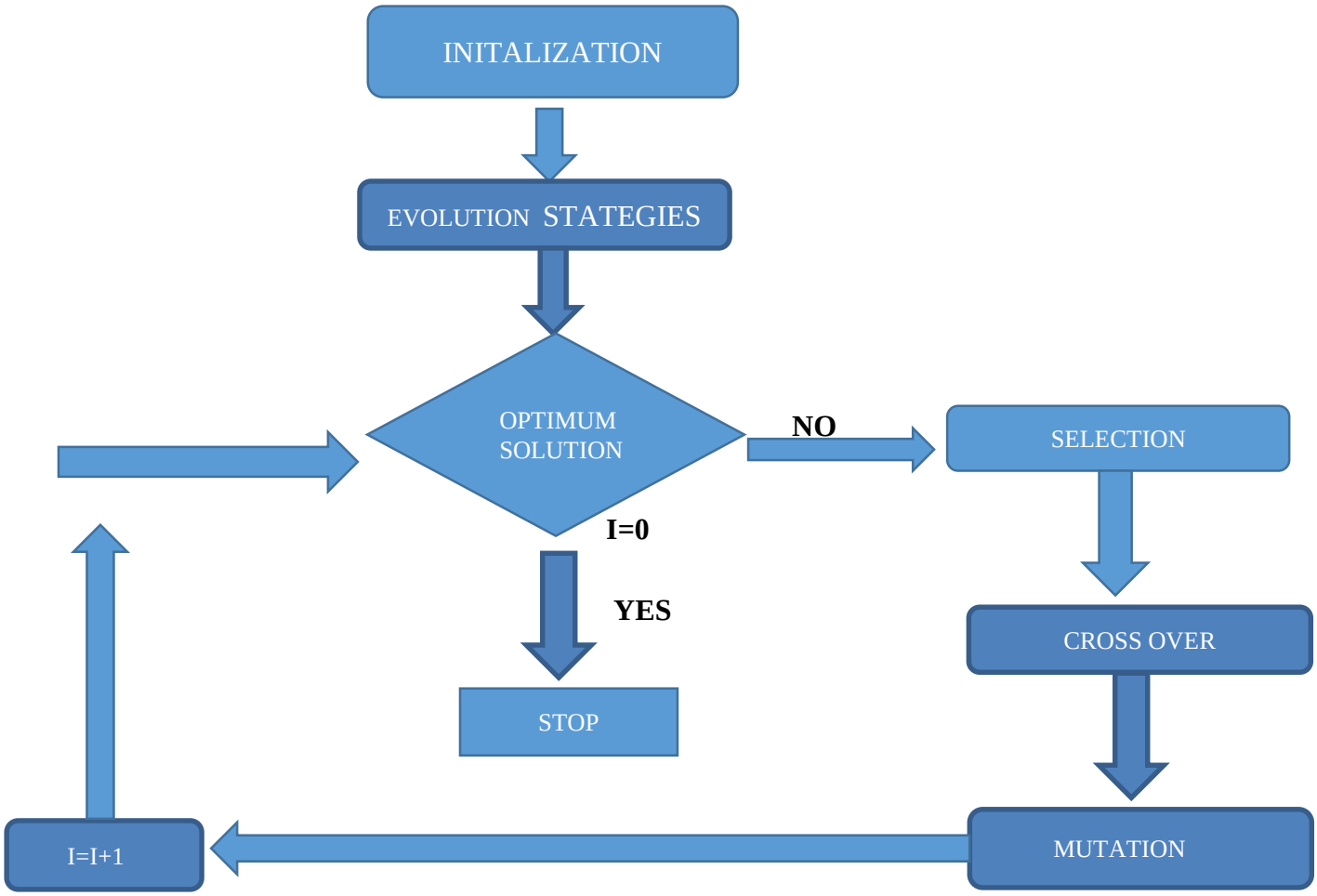


Figure 1: Mechanism of Genetic Algorithm

Table 1: Terminology of Evolutionary Algorithm

Name	Calculation	Additional details
Population	Set of solutions	The quantify of testable chromosomes
Individual	Solution to a problem	Single solution
Fitness	Standard of a solution	Fitness is calculated for each individual
Chromosome	Encoding for a solution(strings)	1 | 1 | 0 | 1
Gene	Part of the encoding solution	1 Or **0**

Libraries visit

• National Medical Library, AIIMS, Delhi

• Manav Rachna International University, Faridabad

Computer Techniques

The following software are supposed to be used:

• MATLAB

• Math Type

6. PROPOSED/EXPECTED OUTCOMES OF THE RESEARCH

The intricacy of human diseases presents both theoretical and practical challenges in abundance. The main aim of this study is to analyze the increasing trend of diabetes and prevent this through the use of different –different mathematical models. Mathematical models can be used in understanding that diabetes can be early preventive through the change in lifestyle. Mathematical models will be help clinically to reduce diabetic cases. Goal of this study is to help in preventing the demise of diabetes.

7. PROPOSED TIME FRAME (GANTT CHART)

Year	Plan of Research Work
1st Year	Coursework & Literature Survey
2nd Year	Visit to Hospital/lab for Data Collection & Creating models with different Parameters
3rd Year	Analyzing & Publishing Research Work
4th Year	Thesis Writing and Submission

Work ↓ / Time →	1st Year		2nd Year		3rd year		4th Year	
	Six months	Six months	Six months	Six months	Six months	Six months	Six months	Six months
Coursework & Literature Survey	←	—	—					
Visit to Hospital/lab for data			←	—	—	→		
Collecting & creating models with Different Parameters								

Analyzing & Publishing				
Research Work				
Thesis Writing and Submission				

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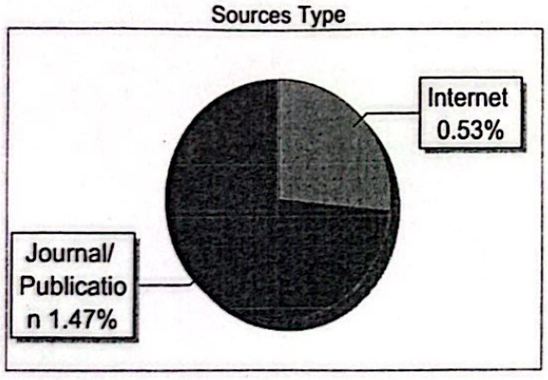

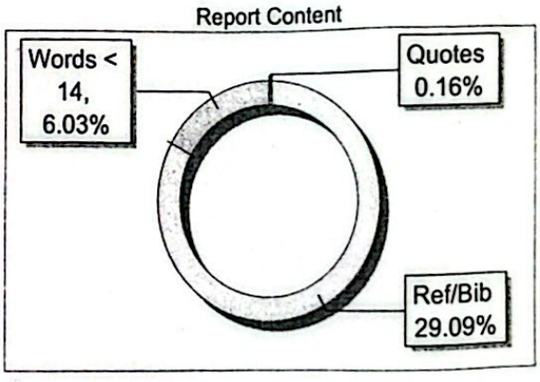

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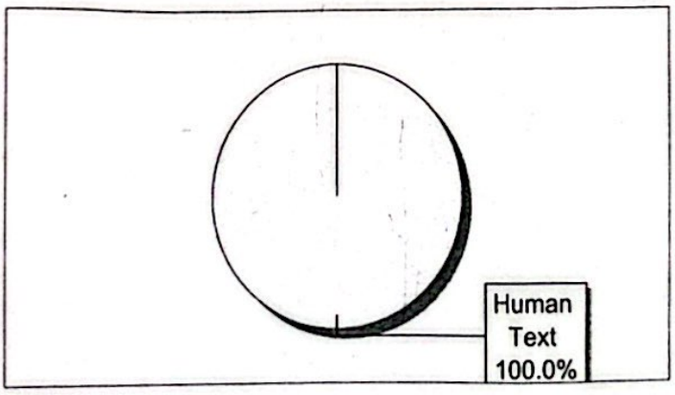
Result Information

AI Text: **0 %**



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